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African Light Source AfLS-2024 (7th)

and the

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Synthesis, Opto-structural and Electrical Characterizations of Nd_2O_3-coated Silicon Nanoparticles

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Aim of the project

- Realising monocrystalline silicon-based solar cells comprising a bilayer of silicon nanoparticles (np-Si) and rare earth neodymium oxide (Nd_2O_3) thin films

Adding silicon nanoparticles and neodymium oxide onto silcon wafer: what for ?

- Coating the surface the silicon wafer with silicon nanoparticles (Si-np) will allow us to functionalize the surface where different nanoparticles size and morphologies could be obtained
- This means $\Rightarrow$ **various optical gap energies (*Eg*)**

Why combine silicon nanoparticles and neodymium oxide (Nd_2O_3) thin films **?**

- These two thin films are optically complementary
- Si-np possess photoluminescent ppropertiies in the visible spectral range (350-850 nm), adding Nd_2O_3 thin layer will enlarge the photosensitivity to the infrared range

$\Rightarrow$ **Higher intensity photoluminescent signal.**

Experimental

Wafer chemical cleaning

NaOH silicon wafer saw damage removal

Native oxide removal: Dip in 3:1 H_2SO_4/H_2O_2 for 20 min at 80°C and 10% HF for 2 min at room temperature

Acetone and ethanol ultrasonic bath

$POCl_3$ phosphorous diffusion

PECVD silicon nitride growth

Nd_2O_3 thermal evaporation

Annealing in N_2 atmosphere

Diffusion and emitter formation

- Thermal phosphor (P) diffusion to create a highly n^+ doped region

  ⇒ Cellule solaire à jonction n^+p

- Emitter formation by $POCl_3$ diffusion using the LYDOP® process
- Diffusion parameters
  - Temperature: 800-850°C
  - Time : 20-40 minutes

Silicon nanoparticles growth

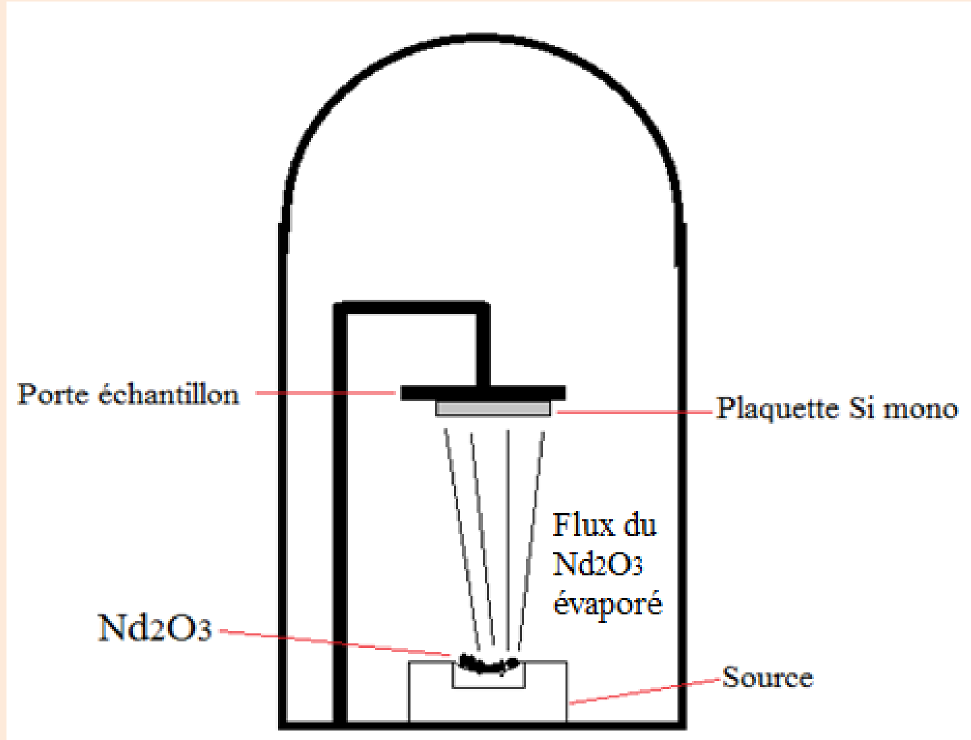
- **Deposition of silicon nitride thin films (SiN) of 80-90 nm via plasma enhanced chemical vapour deposition (PECVD) using ammonia (NH_3) and silane (SiH_4) as precursor gas in the reactor chamber $\Rightarrow$ silicon-rich thin film**

- **Thermal process a change in the phase will occur under the effect of the temperature and the excess of Si in the SiN layer**

New phase (T°+ Si >) $\Rightarrow$ Formation of silicon nanoparticles

Neodymium oxide deposition

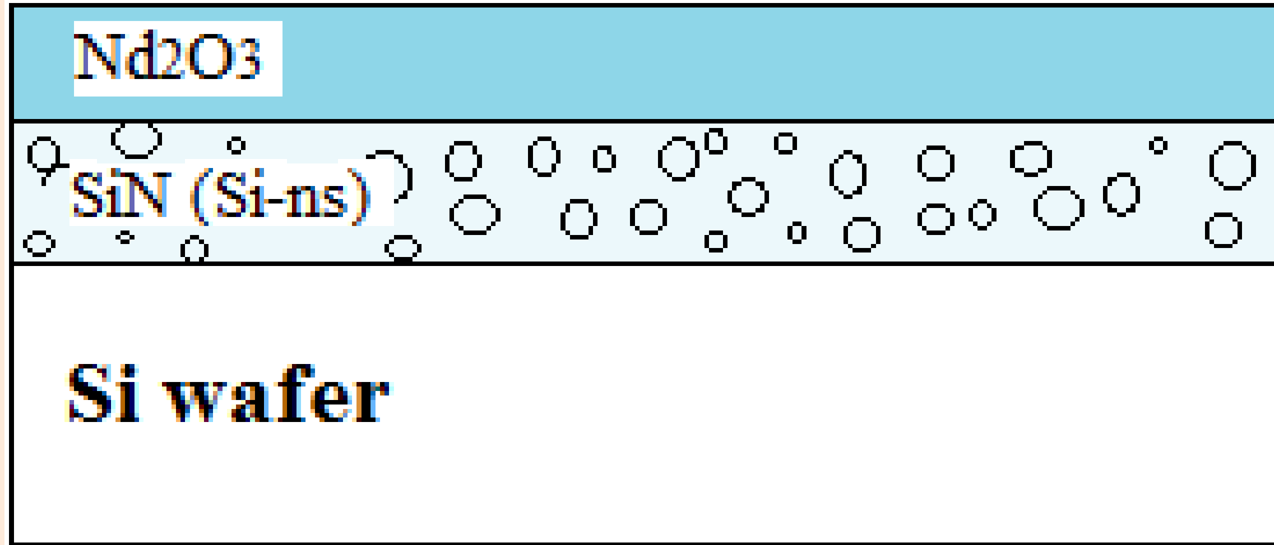
Thin film
Nd_2O_3 (40 - 100 nm)



Annealing under nitrogen

Thermal annealing at a Temperature of

950-1050°C/ 15 – 120 min

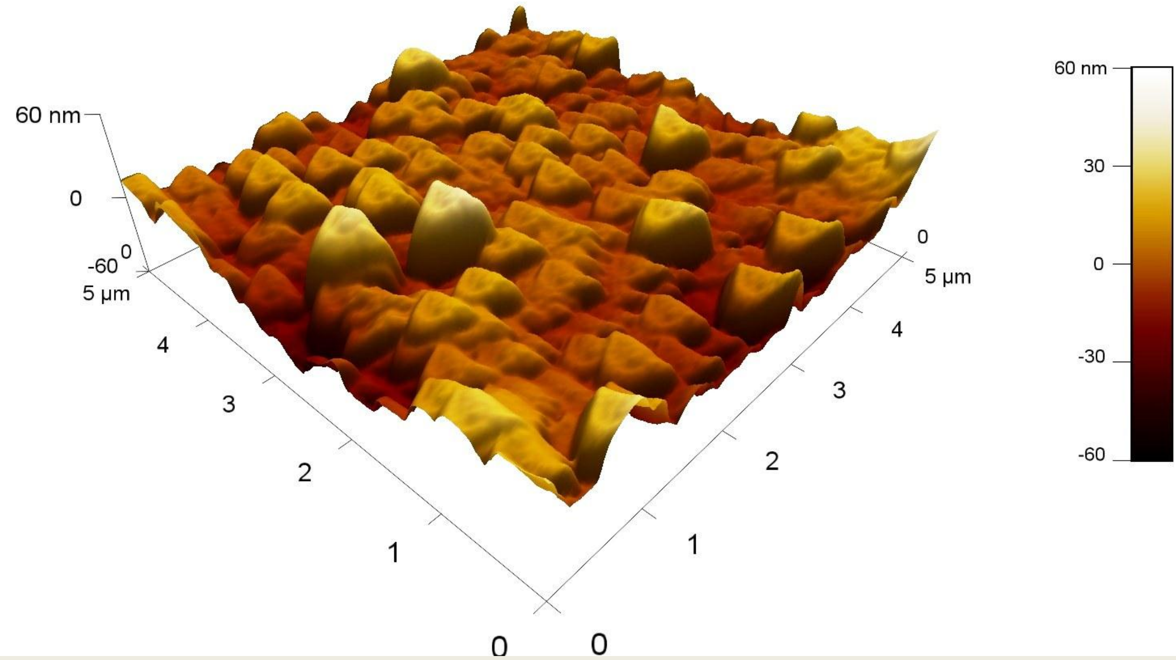


Schematic view of the sample

Atomic force microscopy (AFM)

Gas rate *R*

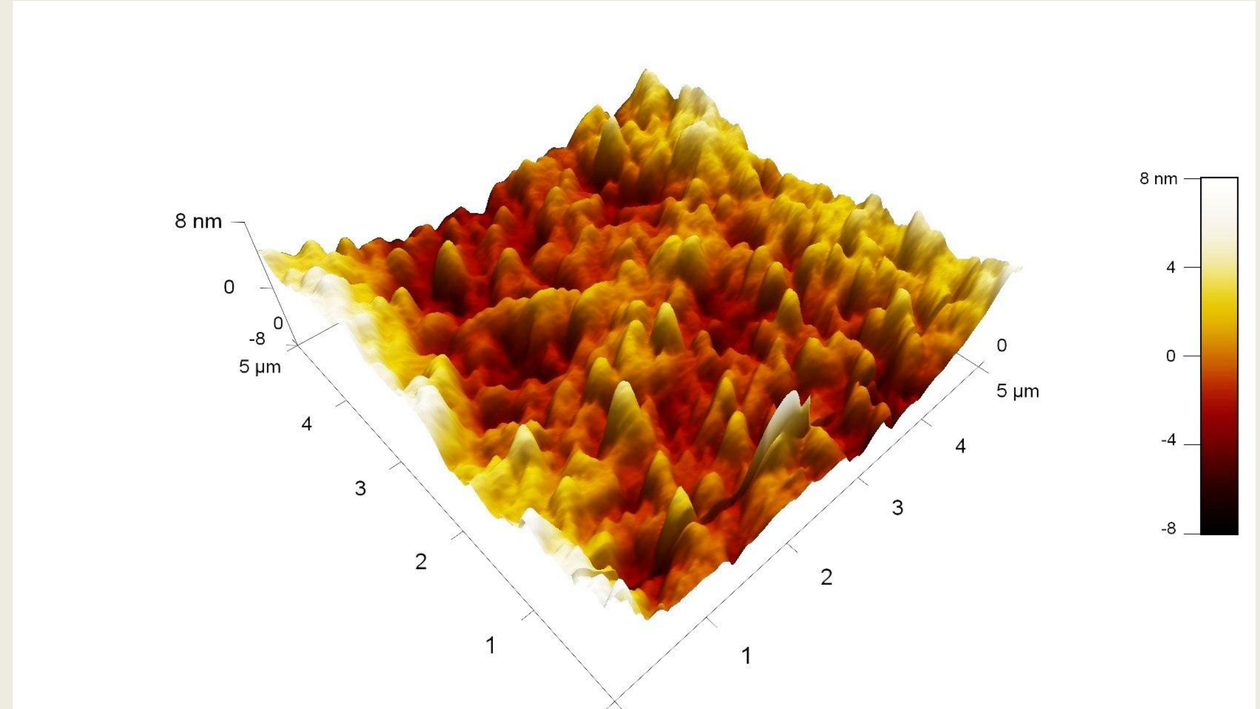
$$\boldsymbol{R} = \frac{NH_3}{SiH_4} = \mathbf{2.5}$$



Results

Atomic force microscopy (AFM)

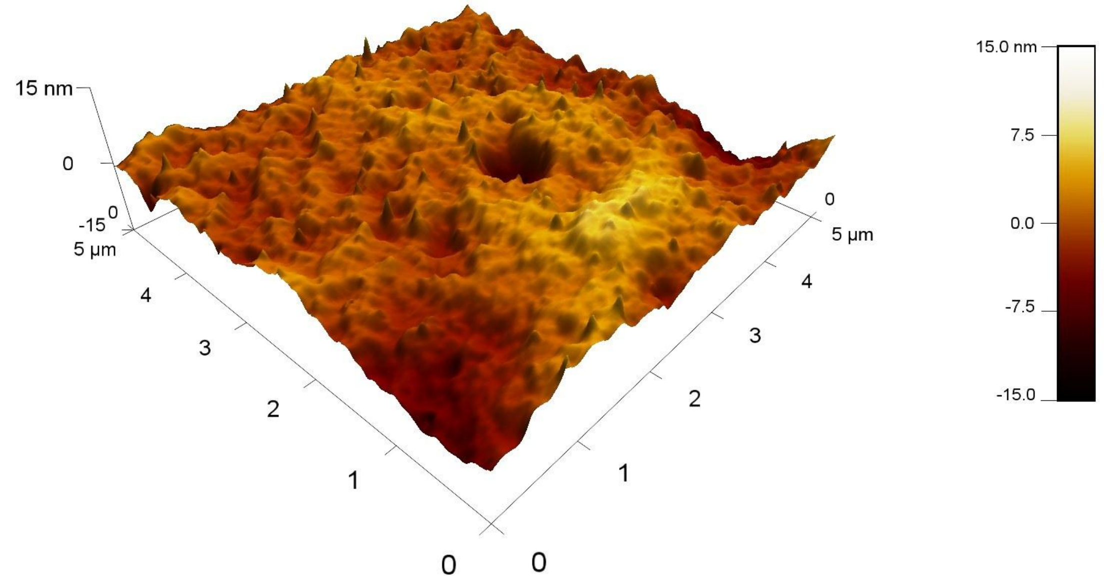
$$\boldsymbol{R} = \frac{NH_3}{SiH_4} = \boldsymbol{3}$$



Results

Atomic force microscopy (AFM)

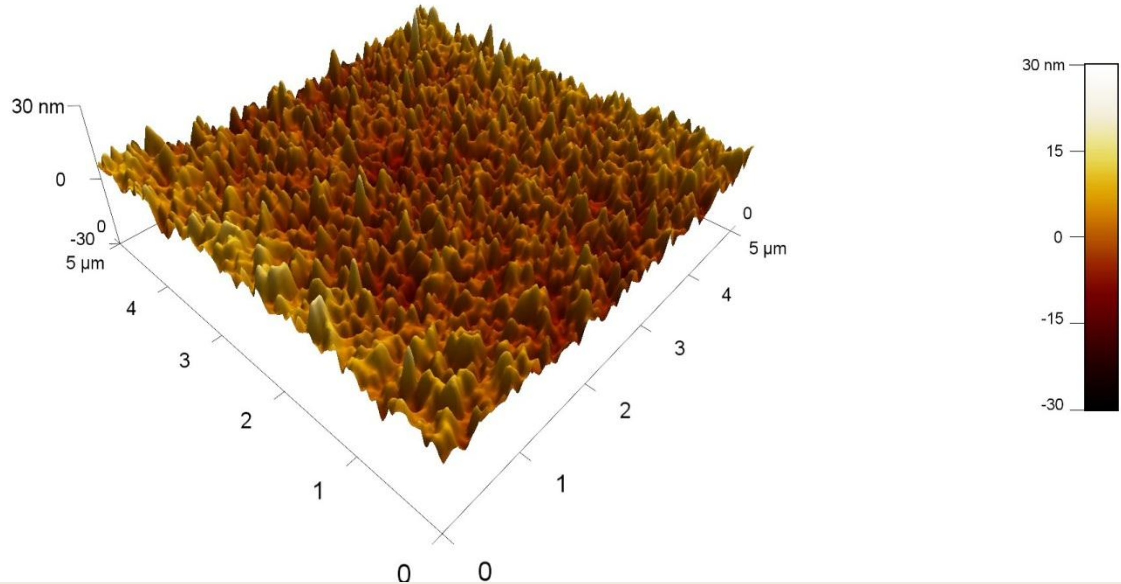
$$\boldsymbol{R} = \frac{NH_3}{SiH_4} = \mathbf{4}$$



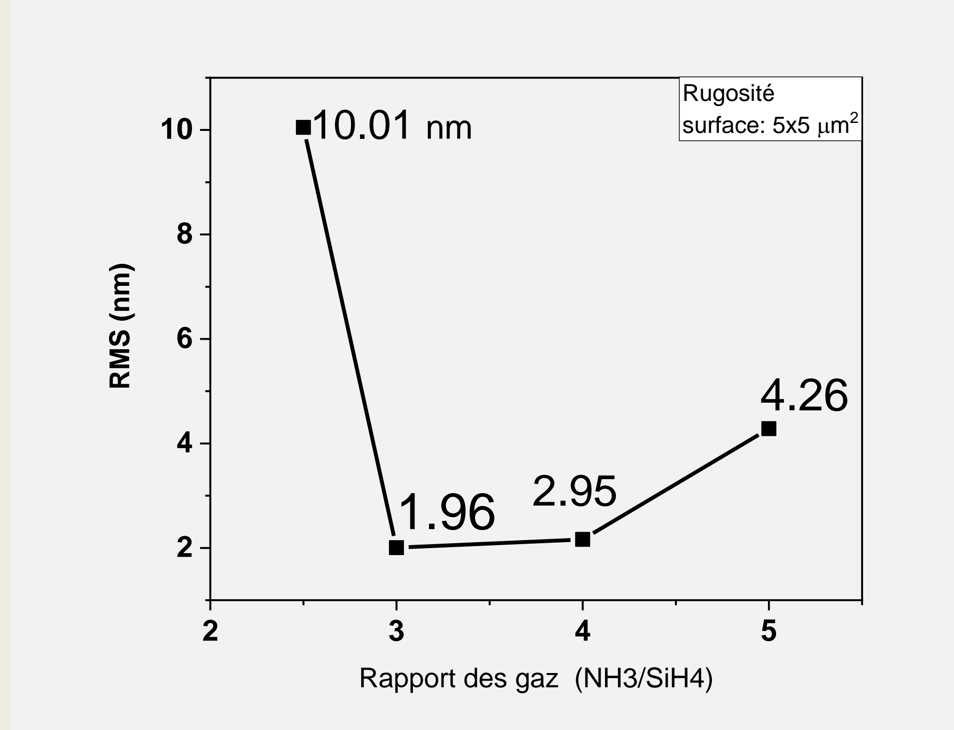
Results

Atomic force microscopy (AFM)

$$\boldsymbol{R} = \frac{NH_3}{SiH_4} = \mathbf{5}$$



Atomic force microscopy (AFM)

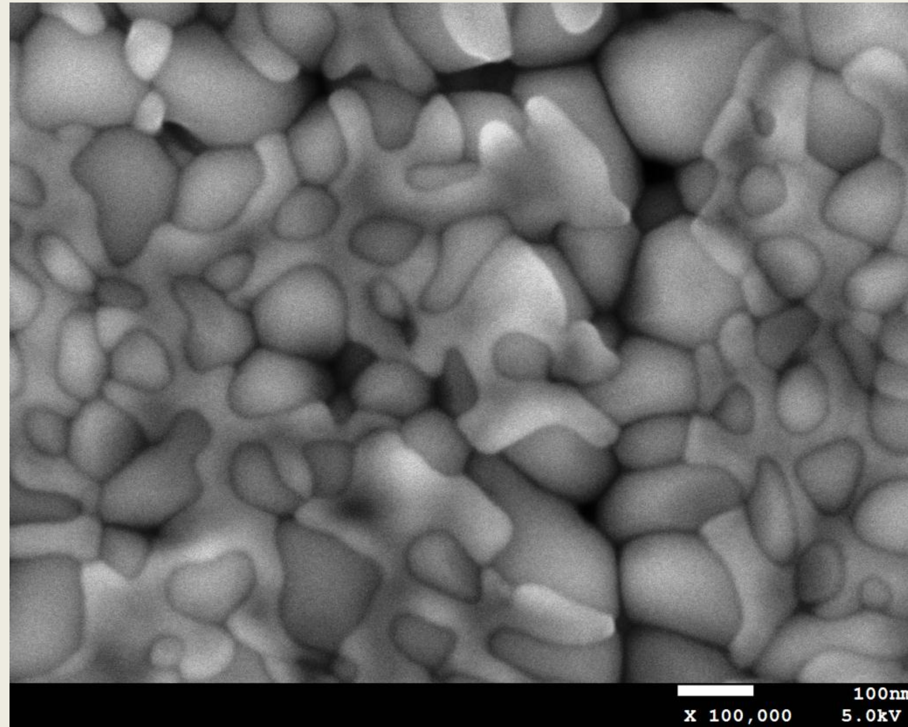


Roughness variation vs (*R*)

Results

Scanning electron microscopy (SEM)

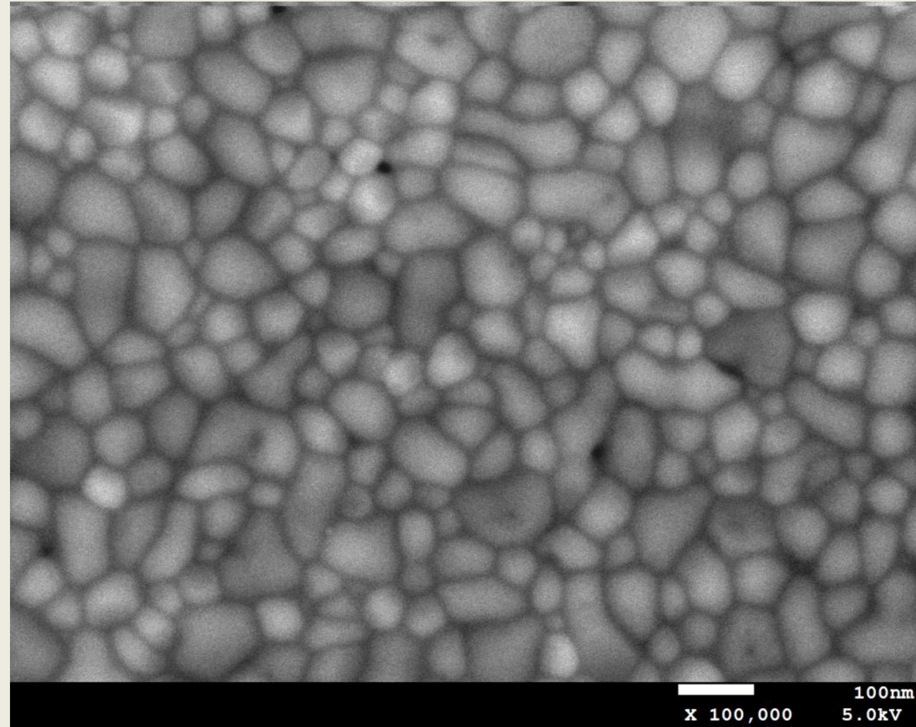
$\boldsymbol{R = 4}$



Results

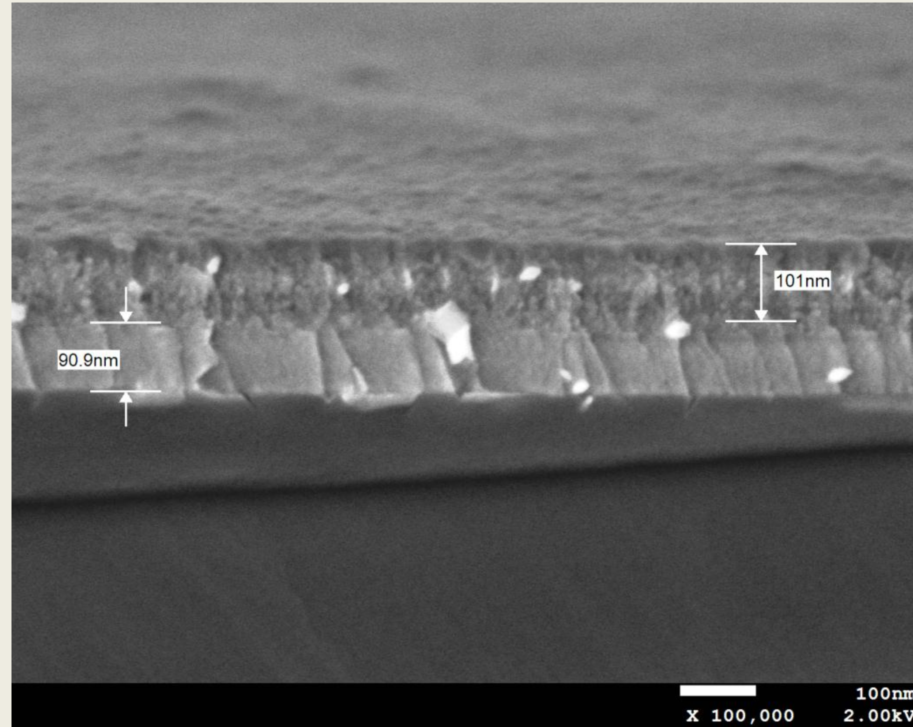
Scanning electron microscopy (SEM)

$$\boldsymbol{R = 5}$$



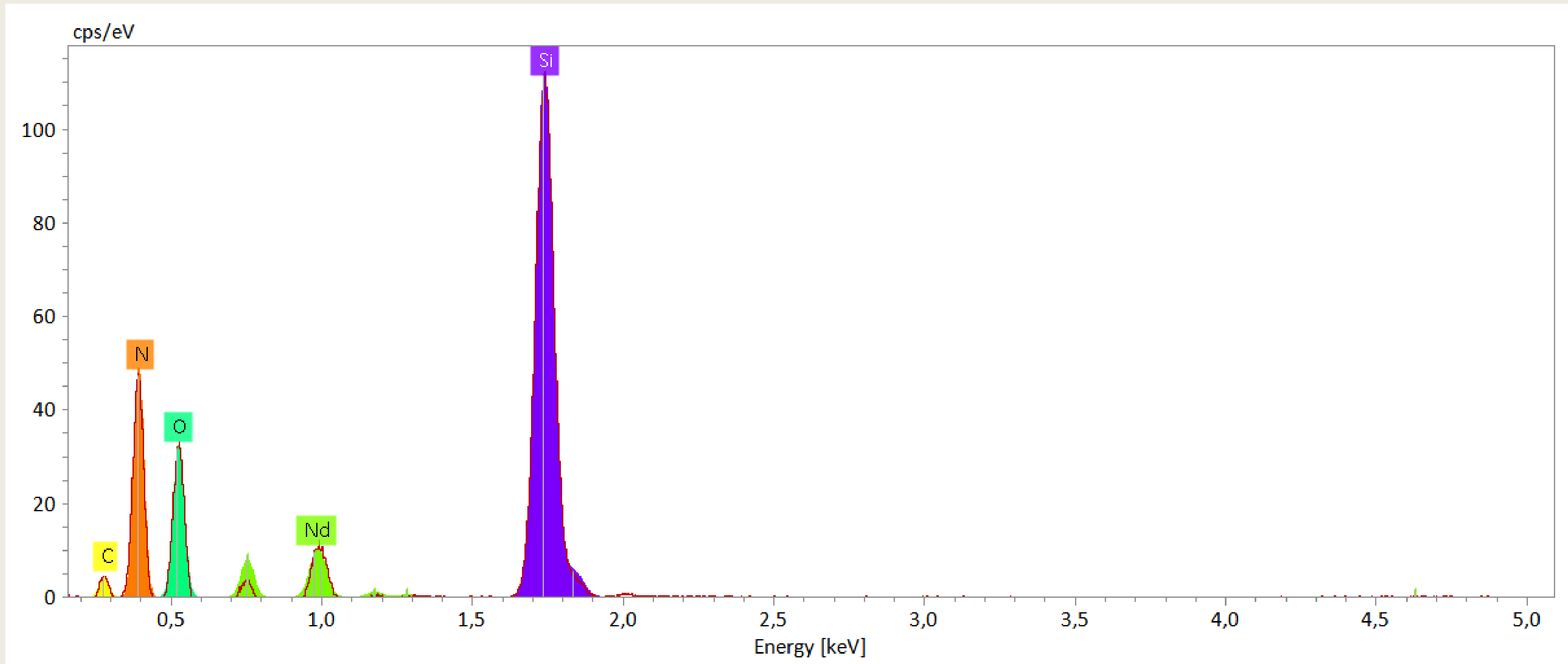
Results

Scanning electron microscopy (SEM)



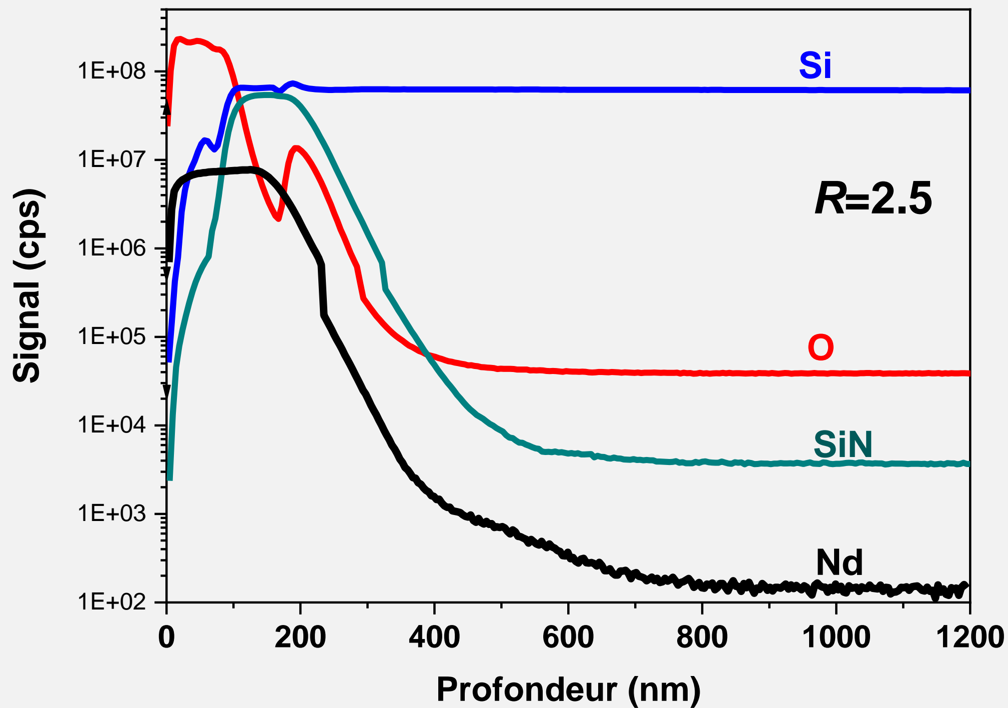
Results

Energy Dispersive Spectroscopy (EDS)



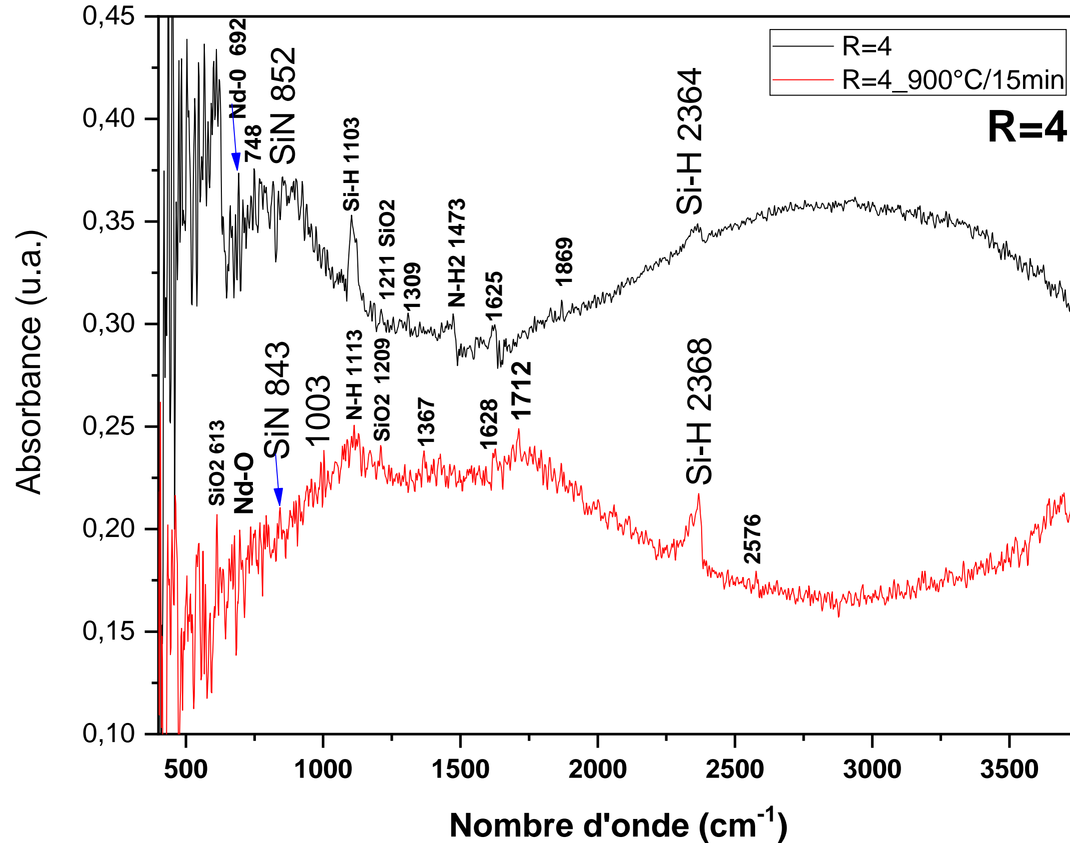
Results

Secondary-ion mass spectrometry (SIMS)



Results

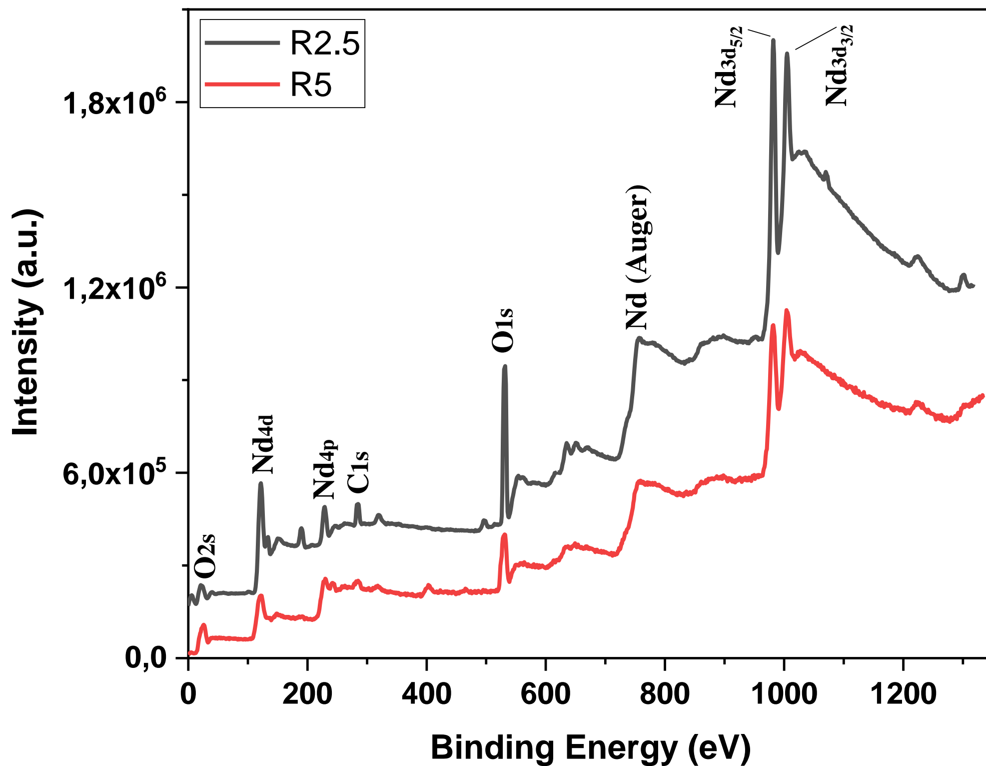
Fourier Transform Infrared Spectroscopy (FTIR)



X-ray photoelectron spectroscopy (XPS)

***R* = 2.5**

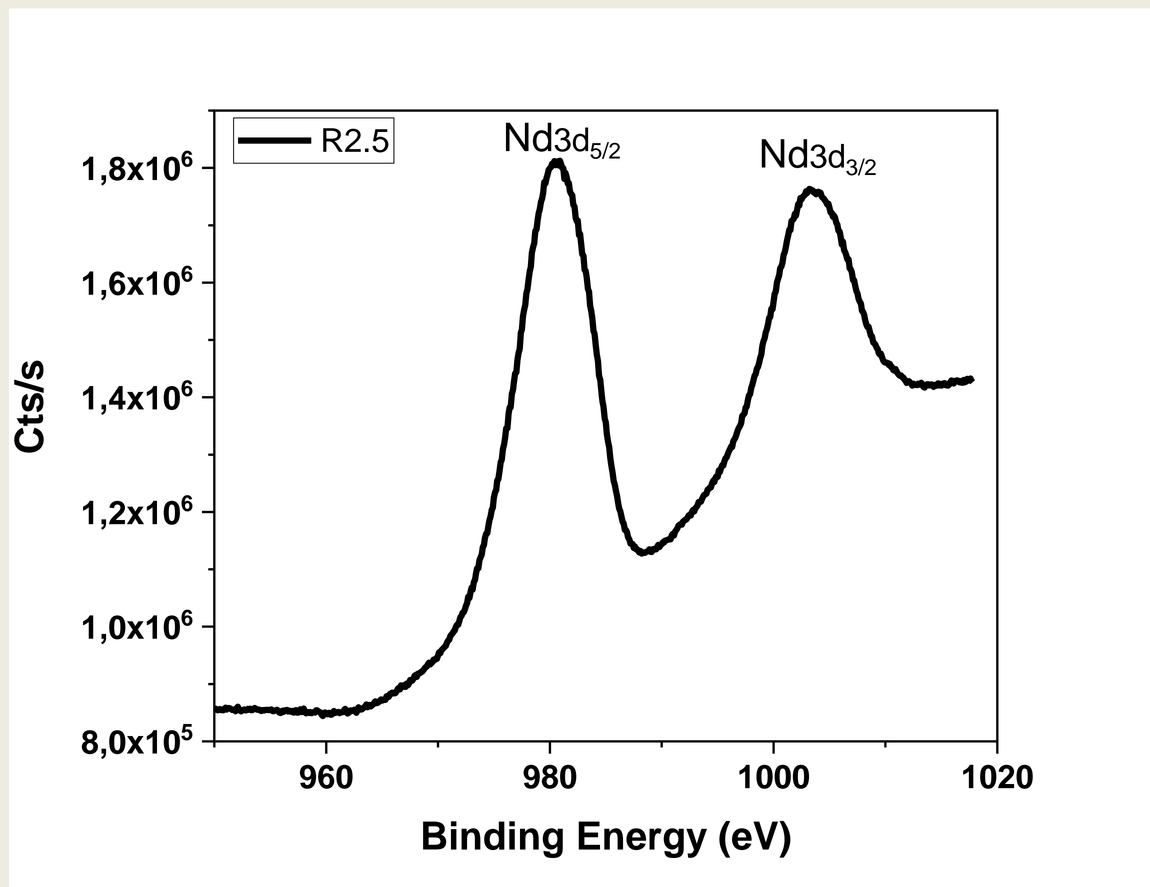
***R* = 5**



Results

X-ray photoelectron spectroscopy (XPS)

***R* = 2.5**

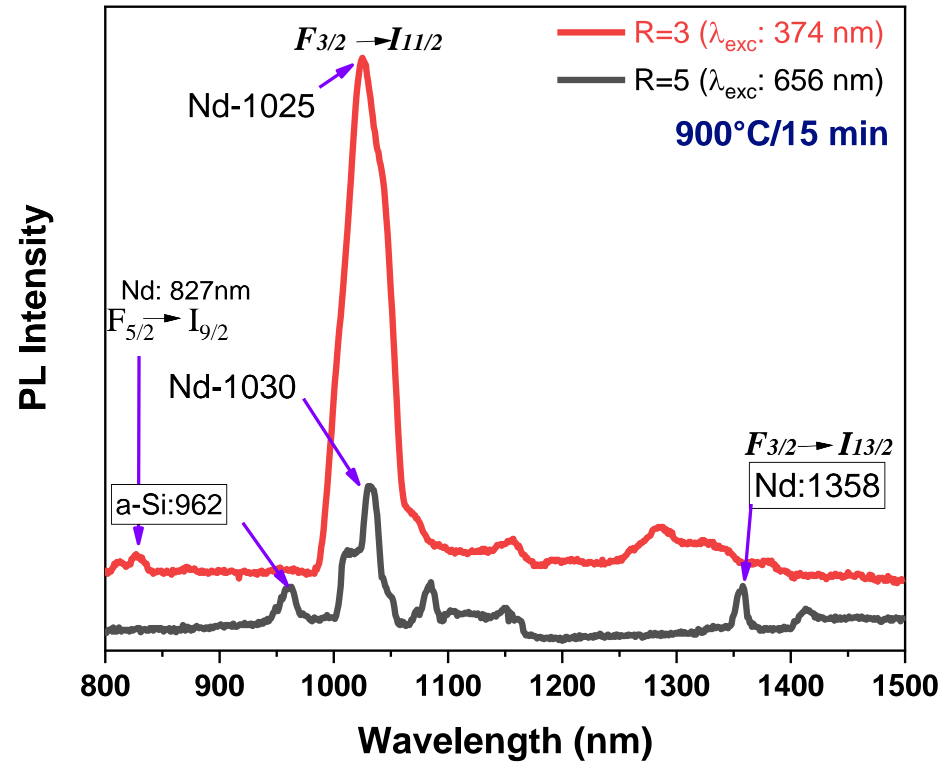


Results

X-ray photoelectron spectroscopy (XPS)

	Binding energy (eV)		
	SiN/Si 1100°C / 2H R=2	Nd_2O_3/SiN/Si 900°C / 15 min R=2.5	Nd_2O_3/SiN/Si 900°C / 15 min R=5
O 2s	24.8	22	26
Si 2p	98.8		
Nd 4d		122	122
Si 2s (SiO_2)	150.8		
Nd 4p		229	230
C 1s	284.8	285	285
N 1s	396.8		
O 1s	528.8	532	530
Nd KLL		757	759
O KLL	977.7– 998.8		
Nd $3d_{5/2}$		982	982
Nd $3d_{3/2}$		1005	1004

Photoluminescence (PL)



Thank You!